



CHATGPT FOR OPERATING SYSTEMS: HIGHER-ORDER THINKING IN FOCUS

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ABSTRACT

Aim/Purpose In this study, we propose an AI technology-based learning model using ChatGPT and investigate its effect on students' higher-order thinking (HOT) ability in an operating systems (OS) course.

Background A critical requirement for IT and engineering students is supporting them in understanding advanced OS concepts and fostering their HOT. HOT involves analysis, evaluation, and creation of new understanding, which promotes deeper learning, improved outcomes, and enhanced student experience. An AI technology-based learning that supports OS instruction and focuses on HOT presents a solution. However, little is known about integrating such an emerging technology into pedagogical contexts, and further investigation is necessary to explore the best design and implementation and investigate its empirical effect. Pedagogical designs with appropriate theoretical foundations should be added to the literature on AI technology-based applications. In this study, we propose an AI technology-based learning model using ChatGPT and investigate its effect on students' performance in handling HOT tasks. Constructivism theory suggests that knowledge is constructed through the individual interactive experiences of learners rather than being passively absorbed. The proposed learning model is inspired by constructivism, which grants students an active role in building their understanding during in-class instruction rather than passively receiving information from the instructor. ChatGPT activities are designed to provide learners with personalized and interactive instruction to build new knowledge about OS topics.

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Methodology	This study comprises 53 undergraduate students enrolled in an OS course offered by the College of Information Technology at AL al-Bayt University in Jordan. The participants were distributed into an experimental group that received AI technology-based instruction using ChatGPT activities and a control group that received traditional instruction. Students were randomly assigned to both groups, and both groups were taught by the same instructor during the academic year 2022–2023. The study was conducted with a quasi-experimental design using a HOT test to evaluate and compare the students’ responses to HOT OS problems.
Contribution	This study is one of the few studies that investigate and measure ChatGPT’s ability to foster students’ HOT. This study offers a novel contribution to the literature by illustrating the viability of employing AI chatbots to improve students’ ability to handle HOT tasks. The effect reported in this study resulting from the use of ChatGPT provides empirical evidence and valuable insights for researchers, practitioners, and educators about the viability of using AI technology-based learning and its related issues. This can guide instructional designers in applying AI-based activities appropriately.
Findings	The findings show that the proposed AI technology-based learning model using ChatGPT improved students’ performance and supported their proficiency in responding to HOT OS tasks that span analyzing, evaluating, and creating cognitive levels. The proposed AI technology-based learning model that employed ChatGPT as a complementary tool helped students analyze, evaluate, and create a new self-understanding of OS topics, which fostered their HOT by 8.9%.
Recommendations for Practitioners	This study recommends that practitioners who utilize ChatGPT should combine other common in-class activities instead of replacing them. Thus, in-class activities become more attractive, increasing their students’ motivation.
Recommendations for Researchers	Researchers need to understand how to design and implement ChatGPT activities and the factors enhancing their positive impact on students and learning.
Impact on Society	AI technology-based learning using ChatGPT can help students improve their learning outcomes and help their instructors deliver content, leading to more efficient and effective higher education. Appropriate design and use of ChatGPT activities within traditional learning activities can promote and encourage the use of such a technology.
Future Research	Additional research should be conducted to explore and measure motivation, engagement, and students’ in-class interaction due to the use of AI technology-based learning. Further experiments on other courses with different environmental variables are highly recommended.
Keywords	operating systems, higher-order thinking tasks, ChatGPT, constructivism theory

INTRODUCTION

Operating Systems (OS) is a core course in computer science and an important requirement for undergraduate programs in computing and some engineering disciplines and, hence, included in their curricula (Kirkpatrick & Prins, 2015; O’Brien, 2017; Pamplona et al., 2017; Webb & Taylor, 2014). Understanding OS concepts and functionalities helps students comprehend many other subjects and

courses (Otero & Aravind, 2015). Many of the ideas and techniques of OS can be applied to other related fields, such as software development. Hence, the study of OS and mastering its concepts provides students with both the experience and knowledge required for their future success (Pamplona et al., 2017). OS comprises several advanced topics and concepts, including CPU scheduling, process management, memory management, and virtual memory (Silberschatz et al., 2018). Learning OS concepts involves additional external knowledge in data structures, computer architecture, and networking to be brought into the course (Manacero & Lobato, 2013). These concepts are difficult to understand, and lots of materials must be covered, requiring additional effort from students and their instructors. Teaching OS to undergraduate students and explaining its topics and concepts has always been a challenge (Kvadsheim et al., 2015; Wagner & Ressler, 1997).

Moreover, higher-order thinking (HOT) is thinking on a level that is higher than memorizing or restating facts (Nofrion & Wijayanto, 2018). It requires students to know and understand the facts, infer from them, and connect them to other concepts. Undergraduate students are required to change the way they study to apply and evaluate lower-level concepts and better align with HOT expectations. HOT involves analysis, evaluation, and creating new understanding, which promotes deeper learning and improves student outcomes by encouraging the questioning of assumptions and consideration of multiple perspectives. This ultimately enhances critical thinking and is essential for academic success and lifelong learning by allowing students to connect new information with prior knowledge and apply it to real-world situations (Chaojing, 2023; Lewis, 2001).

HOT skills are an essential quality of new graduates and are among the most crucial employability skills compared to hard skills. Hence, students with HOT skills are more likely to gain employment and be successful in their chosen occupations (Saat et al., 2023). Fostering HOT can be achieved by teaching students and evaluating their performance at different levels of learning classified by Bloom's taxonomy. Bloom's taxonomy is a common framework that helps incorporate HOT into student learning by categorizing learning and educational goals into lower-order level thinking of remembering and understanding up to HOT levels of analyzing, evaluating, and creating (Bloom et al., 1956). Indeed, HOT leads to effective learning by starting with lower-order levels of thinking as an important basis for encouraging students and moving to higher-order levels of thinking. Because of the importance of such higher thinking levels for students' learning, it is essential to integrate HOT into learning activities, especially for OS, in the context of this study. When teachers help their students develop HOT skills at the top of the revised Bloom's taxonomy pyramid that is shown in Figure 1, i.e., analyzing, evaluating, and creating (Anderson & Krathwohl, 2001), they are targeting the improvement of common 21st-century skills, i.e., critical thinking and creativity, that have recently been trending in education. Considering the importance of the OS subject for juniors and seniors, there is an immense need to foster their HOT and enhance their related skills.

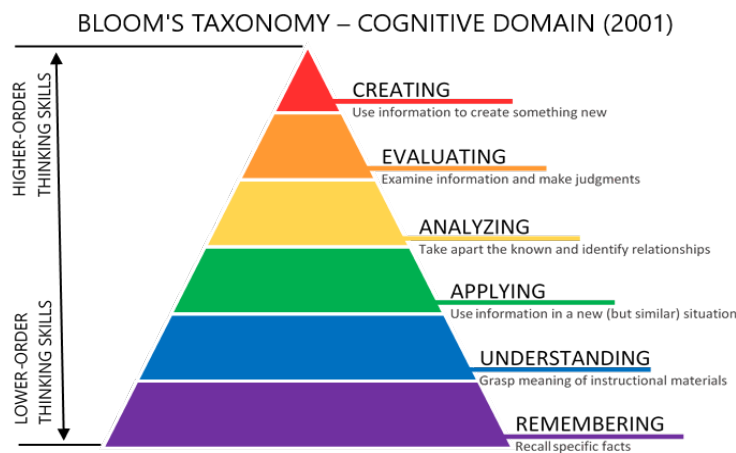


Figure 1. Revised Bloom's taxonomy (Anderson & Krathwohl, 2001)

Consequently, the problem addressed in this study was initiated by the need to help undergraduate students understand OS objectives and grasp its complex topics to improve their responses to HOT tasks, especially with the limited effectiveness of traditional instruction (Kvadsheim et al., 2015). Traditionally, students mainly rely on limited explanations to receive knowledge under limited class time, limited knowledge by the instructor and textbook, and limited additional support provided by other resources such as videos and recordings. Such resources are considered one-way communication and suffer from a lack of personalized and self-learning abilities. Teachers find it difficult to meet advanced OS objectives, and this problem is made worse by the absence of resources and the inability to offer personalized and interactive learning that can help students understand these ideas. Traditional teaching methods such as lecturing, reading textbooks, and watching short videos accessible online have a primary role in education that offer clear guidance of specific skills, reinforce basic skills, and provide structured content and exercises. However, such passive learning, teacher-centered, and one-size-fits-all student teaching methods limit their ability to foster HOT for students (Tomlinson, 2000). Due to the rapid evolution of knowledge, availability of online resources, and distinctive characteristics of today's generation of students, traditional resources provide non-dynamic information, fixed examples, and solutions that cannot satisfy learners' dynamic requirements, especially the OS topics and HOT problems. Such limitations highlight the need for incorporating more interactive, personalized, and student-centered approaches and resources. Additional modern strategies that complement and support traditional methods can help address these limitations and better support the development of HOT skills of students. Traditional teaching can better foster HOT when integrated with interactive elements or critical discussions (Freeman et al., 2014). Therefore, blending traditional OS instructional methods with interactive and collaborative strategies tends to be more successful in supporting students' understanding and application of complex OS issues and improving their ability to handle HOT OS problems.

Further support is required to provide dynamic responses, examples, alternatives, and different methods of explanation in a personalized OS learning environment. Indeed, because students have different learning styles and individual differences, it is important to incorporate various novel classroom activities and teaching techniques. Students are more attracted to a type of learning that enables them to achieve their best performance with less effort, especially with the latest technological developments. Additional effort is needed to get OS students involved in classroom activities, facilitate interactive learning, assist them in achieving their learning objectives, and help them respond more effectively to HOT tasks. This complexity can be facilitated by providing personalized and interactive self-learning experiences with real-time feedback.

In this scenario, the generative pre-trained transformer (GPT) is an AI application that has garnered intense interest in the field of education due to its ability to produce human-like text answers over a wide variety of inputs. The integration of GPT into education can transform traditional teaching methods by providing students with personalized and interactive learning experiences that maintain their motivation, engagement, and achievement (Alajaji & Alshwiah, 2021; Kabilan et al., 2023). Although several common activities, such as brainstorming, picture-taking, rewriting narrative endings, and projects, can be used to support students, AI technology-based activities stand out for their ability to provide self-learning with real-time feedback (Javaid et al., 2023). This helps overcome traditional in-class learning limitations and enhances students' HOT skills (Neji et al., 2023). Among several AI technology-based chatbots produced by GPT models, such as Google BARD, Microsoft Bing Chat, Chatsonic, and WriterZen, ChatGPT has been the most widely discussed language model thus far (Frieder et al., 2023) and has set a new record for the fastest-growing consumer application in history (Hu, 2023) – this is why we gave it the primary focus in this study. ChatGPT is the original and most popular AI chatbot used in the educational field (Sánchez et al., 2020). ChatGPT can support the instructional process and is useful for students and their teachers because it offers personalized and interactive learning experiences and can offer a wide range of computational problems with several alternative solutions and clear explanations (Husain, 2024). ChatGPT can help students analyze,

evaluate, and create a new understanding of complex ideas by providing diverse real-time explanations and rich examples with self-interactive learning.

This study posits that AI technology-based activities using ChatGPT provide a promising solution to facilitate the complexity of OS topics and foster HOT for their students. Additional support using ChatGPT instructional activities that offer personalized interactive learning with immediate feedback might be helpful for students to tackle such multidisciplinary and complex courses better. A learning model with a proper theoretical foundation that enables individual and personalized learning for OS students using AI chatbots instead of instructor-dependent learning is highly required.

Until now, there have been limited studies on the empirical effects of ChatGPT on undergraduate students' performance and their abilities to tackle HOT tasks, particularly for IT subjects like OS (Wardat et al., 2023). Little is known about how to integrate such an emerging technology into a pedagogical context, and there are no satisfactory results regarding its potential effects on learners. Further studies using different environmental variables (subjects, students, learning strategies) are needed to explore the best design and implementation and to investigate technology's practical efficiency. Pedagogical designs with appropriate theoretical foundations should be added to the literature on AI technology-based applications. Accordingly, we conducted this study to fill such research gaps by employing an AI technology-based learning model via ChatGPT and measuring its effects on students' responses to HOT OS tasks. Guided by constructivism theory, we posit that students' performance and their HOT can be improved when ChatGPT activities are correctly integrated into traditional teaching methods that offer a personalized learning environment. Constructivism suggests that knowledge is constructed through the individual interactive experiences of learners rather than being passively absorbed. ChatGPT can provide learners with personalized and interactive instruction to build new knowledge about OS topics. The proposed learning model is inspired by constructivism, which grants students an active role in building their understanding during in-class instruction rather than passively receiving information from the instructor. Additionally, students can analyze, evaluate, and create new knowledge and incorporate their prior knowledge into their schemas.

The aim is to introduce AI technology-based learning that employs ChatGPT in-class activities that complement other OS classroom activities and empirically investigate their effects on students' HOT performance. The findings of this research could provide significant insights regarding integrating AI chatbots such as ChatGPT into IT courses (i.e., OS) and lead to a better understanding of the best methods of integration with maximum benefits and educational implications. This study can offer educators and educational institutes guidance for efficient use in OS instruction and other similar IT and engineering subjects. In this study, we sought to answer the following research question:

- Does the AI technology-based instructional approach using ChatGPT significantly impact students' ability to tackle HOT tasks when studying operating systems?

BACKGROUND AND LITERATURE

CONSTRUCTIVISM THEORY

The theory of constructivism is defined as generative learning, in which knowledge is constructed, and meaning is created from what students learn individually. According to constructivism, students can study and understand new concepts efficiently by building new knowledge through individual interactive experiences that are integrated into previous knowledge. Perceiving new knowledge passively by a direct process of knowledge transmission is not an efficient way to acquire and understand new knowledge. This theoretical foundation motivated several researchers to investigate the effectiveness of constructivist-based approaches in teaching, showing promising results for improving student performance (Galia, 2016). Constructivist teaching helps develop cognitive skills because the learner plays an active role in the learning process (Sharma, 2014). Constructivism also emphasizes the importance of social interaction and collaboration in learning. It helps develop

cognitive skills because it provides opportunities for learners to negotiate ideas, perform challenges, and build a shared understanding. Constructivism, therefore, posits that the learner has recent prior knowledge and experiences that often result from previous information. That information can inspire the learner to move toward higher cognitive levels, that is, HOT skills. Learning is therefore accomplished by students' "constructing" knowledge from their experiences, starting with lower-order thinking levels and moving toward HOT levels in a socially interactive way.

In sum, constructivism's main idea is that human learning is constructed and that learners build new knowledge upon the foundation of previous learning. Thus, building on this theoretical foundation, we posit that ChatGPT can help students obtain new understandings of OS concepts that can easily be integrated into their previous related knowledge through interactive self-learning experiences. Students can move from basic thinking (i.e., lower-order thinking tasks) to HOT OS problems. Indeed, the proposed learning model is inspired by such a foundation by introducing the intended topic of the lecture initially in the first part, then allowing students to construct knowledge personally using ChatGPT based on their prior information. Lastly, collaboration, among others, should be allowed through class discussion in the last part of the lecture.

AI-BASED LEARNING

OS is an essential subject for undergraduate students pursuing their degree in computer science or engineering and is included in their requirements (Kirkpatrick & Prins, 2015; O'Brien, 2017; Webb & Taylor, 2014). Several strategies have been implemented to improve OS teaching and overcome its issues. An example is the use of graphical simulators in OS instruction to provide a visual representation to facilitate understanding of how OS works by observing events at each moment (Cañas, 1987). The learning environment approach employs software applications to teach and learn OS. Collaborative learning techniques are used to improve learning in OS by emphasizing student interactions rather than learning as a solitary activity (Prince, 2004). Educational games are also used as OS teaching, as are learning tools that offer opportunities for students to practice various concepts and skills (Bodnar et al., 2016). However, additional support with interactive learning, additional explanation and clarification, adaptability, and instant feedback may be more helpful for students to handle such multidisciplinary topics better and improve their performance.

Recently, innovative AI tools such as chatbots have become increasingly utilized in educational contexts, offering personalized student learning and expanding their opportunities, collaboration, and accessibility (Wu & Yu, 2023). Indeed, providing personalized learning, automated assessment, predictive analytics, and learning analytics advantages can significantly improve instructional strategies and the instructional process for teachers and students (Husain, 2024). Consequently, several educational benefits of using AI tools have been reported recently. For instance, AI can help educational institutes and their teachers reduce workload by automating student evaluation with high levels of accuracy, reliability, and validity, predicting academic performance, identifying potential at-risk students (Baker, 2021), and enhancing curriculum design by identifying trends and patterns that can inform appropriate improvement in instructional decisions (Shum et al., 2019). For students, AI proved its ability to enhance their learning outcomes (Baker, 2021; Rodriguez-Alvarez et al., 2020), provide personalizing feedback (Alhajjaji et al., 2021), enhance their engagement and academic achievement (Popenici & Kerr, 2017), and enhance their motivation (Oktradiksa et al., 2021).

Moreover, several educational applications of AI chatbots, such as ChatGPT, have been investigated in specific domains and disciplines, such as language, science, and programming, with outstanding results. Indeed, AI improved student performance in language learning (Zhu et al., 2023), improved problem-solving and conceptual understanding of physics (Kortemeyer, 2023; Rowe & Lester, 2020), enhanced students' problem-solving skills and their understanding of complex biological concepts (Aminoshariae et al., 2021), and enhanced students' understanding of basic chemistry concepts with efficient learning (Choudhary et al., 2021). In the field of IT education, studies have demonstrated several abilities of ChatGPT and its efficiency in supporting students to perform computational tasks

and solve advanced problems (Biswas, 2023), improve students' programming skills (Chen et al., 2023), improve their computational thinking (Yilmaz & Karaoglan Yilmaz, 2023), and enhance their academic performance in data structures and algorithms (Qureshi, 2023).

However, while several educational benefits of ChatGPT have been reported, this outstanding performance might vary across subject domains, ranging from satisfactory to unsatisfactory (Lo, 2023). For instance, ChatGPT's capability in mathematics is claimed to be unsatisfactory, falling short of the level of average students due to imprecise answers for a given input (Frieder et al., 2023). Another investigation by Wardat et al. (2023) about ChatGPT performance in mathematical educational scenarios revealed various performance issues and a lack of a deep understanding of geometry. ChatGPT also provided unsatisfactory performance in the sports science and psychology domains with low scores (Methnani et al., 2023; Szabo, 2023). The poor performance of ChatGPT in performing software testing and training was also revealed by Ahmad et al. (2023) and Zhang et al. (2023). Several limitations to using ChatGPT were observed, including potential biases, the inability to process visual information, privacy and security issues, and misuse of ChatGPT by obtaining ready solutions without understanding (Fiilalka et al., 2023; Rahman & Watanobe, 2023). Furthermore, several challenges have been reported due to the integration of ChatGPT in the educational context. Halaweh (2023) emphasizes the need for responsible implementation strategies when integrating ChatGPT into educational settings, which acknowledges the risks of overreliance and the generation of inaccurate information. Sok and Heng (2023) review ChatGPT risks in education and emphasize the need for mitigation strategies and the integration of other educational resources. Mhlanga (2023) provides insights into the responsible and ethical use of ChatGPT in education, highlighting the need for transparency, fairness, and privacy protection.

Indeed, there needs to be more practical evidence regarding ChatGPT's efficacy in enhancing educational performance in IT and computer disciplines, especially HOTS for undergraduate students. Limited research focuses on HOTS skills and has identified several issues (Guo & Lee, 2023; Susnjak, 2022). A descriptive study by Guo and Lee (2023) revealed that ChatGPT provided diverse students' perspectives and challenged their ways of thinking, which enhanced their critical thinking skills. However, concerns have been raised, including low-quality student comments and difficulties validating information sources. Susnjak (2022) evaluated the ability of ChatGPT to perform high-level cognitive tasks and produce text similar to human-generated ones, but as a concern that might affect academic misconduct in online exams. The study found that ChatGPT is capable of exhibiting critical thinking skills and generating highly realistic text with minimal input, making it a concern that threatens online exam integrity, particularly in higher education settings.

The contradicting results of such investigations propose several avenues for research that ought to be explored to guarantee the best integration of AI chatbots, especially ChatGPT, into higher educational contexts. Therefore, the study aimed to explore how ChatGPT can foster HOTS among students, especially in OS, through an AI-based personalized learning environment. Indeed, little is known about how to integrate such emerging technology into pedagogical contexts and teaching practices. Additional studies using different environmental variables are needed to explore the best design and implementation of AI technology-based learning models and provide additional knowledge on the best method for integrating AI chatbots into IT courses. Further research is needed to fully understand how to integrate large language models like ChatGPT in such a way that fosters the HOTS of the students. Educators and institutions must be aware of the possibility of ChatGPT being used to improve HOTS rather than focusing on lower-order thinking for all students. Additional studies will provide valuable input for developing the effective use of AI in programming instruction and pedagogical practices for instructors, students, and curriculum developers. Instructional strategies and designs with theoretical foundations should be added to the literature on AI-based learning and ChatGPT integration.

METHODS

SUBJECTS

This study included 53 undergraduate students who were enrolled in an OS course offered by the College of Information Technology at al-Bayt University in Jordan during the academic year 2022–2023. The participants were randomly assigned into two groups: the experimental group ($n = 23$) received AI technology-based instruction using ChatGPT activities, and the control group ($n = 30$) received instruction using the traditional approach, as shown in Table 1. Both groups received the same instruction over 14 weeks – two lectures a week. The experimental group received additional ChatGPT-based instruction for 30 minutes per lecture, while the control group received traditional instructional activities for the same time. ChatGPT was used in this study to practice personal self-learning through AI web-based activities that generated coherent text and answered questions in natural language and visual knowledge. The ChatGPT activities were designed to provide personalized and interactive OS instruction for the students during in-class instruction.

Table 1. Participants of the study

Groups	Male	Female	Subtotal
Experimental	12	18	30
Control	10	13	23
Overall total			53

The study is conducted with a quasi-experimental design using a HOT test to evaluate and compare the students' responses to HOT OS problems.

INSTRUMENT

In this study, we measured and compared the effectiveness of AI technology-based instruction using ChatGPT instruction with traditional classroom instruction in improving students' ability to tackle HOT OS tasks and topics. To assess the participants' ability to handle HOT tasks, we administered a test that measures HOT OS concepts after the instruction was completed for both groups. The test consisted of questions that span the HOT cognitive levels of Bloom's taxonomy, which are analyzing, evaluating, and creating, where each item represents and measures one HOT OS objective. The test items were deliberately chosen from an item bank that the course textbook's author had built. The item bank was based on the course objectives, including many items of varying difficulty levels that addressed the HOT cognitive levels corresponding to each objective. We evaluated the content validity of the test by presenting it to a validation panel of multiple seasoned instructors and experts in their fields and in test construction. The final test items were chosen based on their assessments of the items' distribution across the relevant content areas and the assessed HOT cognitive levels.

The test items were specified in a table format and were intended to evaluate OS-related objectives. The test comprised 20 multiple-choice items and six scenario items. In the multiple-choice questions, a correct answer was awarded one point; an erroneous answer was given zero points. Each scenario question was worth five points, and the total score could be as high as 50 or as low as zero. The stratified alpha coefficients for the test were computed and found to be within an acceptable range (0.89). An example showing proposed memory management objectives according to Bloom's HOT skills is presented in Figure 2, and their corresponding test item sample is presented in Table 2.

Bloom's taxonomy for Memory Management

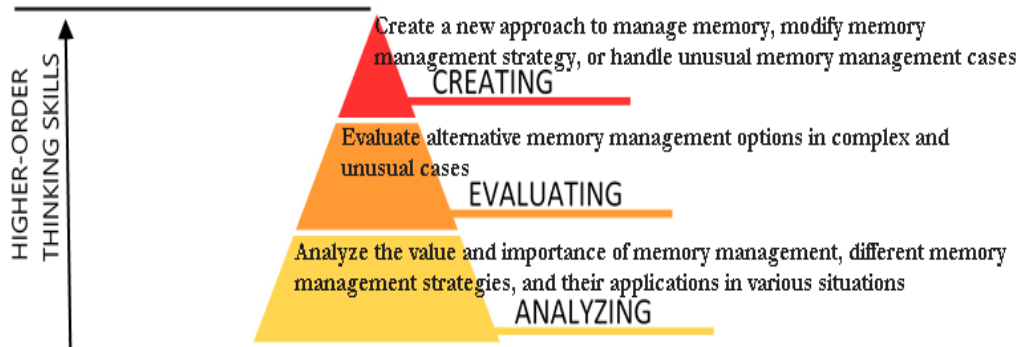


Figure 2. Bloom's taxonomy with a practical OS example (memory management)

Table 2. An example of test items that span HOT levels for memory management

Higher-order thinking test items	Bloom's cognitive level (HOT)
Explain why page sizes are always powers of 2	Analyzing
Calculate how many bits there are in the logical address and physical address for an 8-page logical address space with 1024 words for each, mapped onto a physical memory of 32 frames.	Evaluating
Assuming a paging system with a page table stored in memory, formulate how long a paged memory reference takes if the memory reference takes 200 nanoseconds.	Creating

PROCEDURES AND THE PROPOSED LEARNING MODEL

The experiment began during the 2022–2023 academic year for both groups and lasted for 14 weeks, with two 75-minute teaching sessions per week. The control group received instruction using traditional instructional techniques, which included face-to-face lectures in addition to other common learning in-class activities such as brainstorming, quizzes, presentations, case studies, asking questions, discussions, and group learning. The experimental group's lessons were augmented by the proposed AI technology-based learning method using ChatGPT.

To answer the research question, we proposed an AI technology-based learning model for experimental group instruction. The proposed AI technology-based learning model depends primarily on designing and implementing ChatGPT activities integrated into learning objectives to create an AI-like environment. Our design of the proposed model was consistent with and supported by the theory of constructivism in that the individual learner plays an active role in the learning process. ChatGPT can achieve and support personalized self-learning. Properly integrating ChatGPT into OS learning, especially with the existing unstructured learning, raises several issues, such as selecting or formulating questions, obtaining undesired responses, and efficiently understanding and interpreting ChatGPT responses (Husain, 2024). Therefore, to effectively overcome such issues and help achieve the intended learning objectives, we introduced a complementary role for ChatGPT within the classroom under the instructor's supervision. The OS learning objectives were first delivered by the instructors and then supported by ChatGPT activities as individualized learning.

Consequently, to measure and compare the ability of ChatGPT to improve students' responses to HOT tasks, the experimental group was taught using an AI technology-based instructional model

parallel to the traditional control group. Each ChatGPT-based activity was mapped to a learning outcome derived from textbook objectives (HOT tasks, for instance), and several tasks were prepared by the instructor before the in-class lectures, including problem details, potential questions for ChatGPT, and ideas about the expected results. To follow up with the study experiment, the first part of the lecture was designated for traditional instruction by the instructor; an AI-based interaction session was then established in the second part with directions including a clear learning outcome, a corresponding problem to solve, and potential related questions before each ChatGPT-based activity. Students could also get support during their interaction sessions with ChatGPT, which included formulating questions and interpreting responses. For each ChatGPT-based activity, students were given directions to deploy ChatGPT to solve or generate additional explanations for a given problem.

The instructor initiated the AI-based interactive session of each lecture by displaying the intended ChatGPT-based activity details (i.e., problem details, potential questions for ChatGPT, and ideas about the expected results) on the main presentation screen in the class. An example of an AI-based interactive session initiated by the instructor for one of the lectures about the Shortest Job First scheduling algorithm is presented in Appendix A as an example. Consequently, while students were communicating with ChatGPT, they had to work on the related questions and then interpret the related responses using their web-connected mobile phones. Students could perform a self-summarization of the final result, indicating their conclusion and acquisition of knowledge during their interaction with ChatGPT. Students could also perform self-evaluation by comparing the obtained ChatGPT results with their summarized solution for that problem when required. An overall discussion was conducted in the class among all students, discussing the results and any additional issues that had emerged from that problem or case study. Students’ tasks during their ChatGPT interaction included formulating ChatGPT prompts, interpreting ChatGPT responses, self-summarization, and self-evaluation. Finally, students were required to capture and report their progress during their ChatGPT interaction session, including the ChatGPT prompts and their responses. They also had to report their self-summarization and self-evaluation as a PDF file and submit it to a homework post on Moodle LMS. At the end of the ChatGPT-based activity session, the best reports observed during discussions were presented on the main presentation screen in the class and discussed to provide further benefits to other students. In contrast, student-instructor interaction was conducted in the second part of traditional group instruction, including direct instructions, illustrative examples, class group discussions, and assignments. Finally, to measure and compare students’ performance in the AI technology-based instructional group with the traditional group, the HOT test was conducted in the last week of the experiment at the end of the instructional period for both groups. The ChatGPT learning model and the traditional model are presented in Table 3.

Table 3. ChatGPT learning model vs. traditional model

Learning model	First part of the instruction	Second part of the instruction			
ChatGPT-based	Discussion, presentation, questions, answers	Problem determination (objective)	ChatGPT Interaction (interactive learning)	Self-summarization and self-evaluation	Class group discussion
Traditional	Discussion, presentation, questions, answers	Problem determination (objective)	Student-instructor interaction		Class group discussion

A real-time challenge was occasionally conducted among students during selected lectures by asking them to identify a specified problem or scenario within a specified period. This challenging design helped increase students’ engagement and participation. The instructors supported tasks such as for-

mulating ChatGPT prompts, interpreting ChatGPT responses, and summarizing the overall responses about a specific topic. In some cases, instructors assigned additional out-of-class ChatGPT-based activities to students.

Appendix B presents an example of a ChatGPT interaction session, showing questions posted and responses generated for one student communicating with ChatGPT to build knowledge about the Shortest Job First scheduling algorithm as an example.

RESULTS

To measure students' performance in the AI technology-based instructional group and evaluate the ability of ChatGPT to improve their responses to HOT tasks, we applied analysis of variance statistics to the students' performance on the HOT test scores of both groups. Initially, before conducting data analysis, we used several assumptions to examine the normal distribution and homogeneity of the data. For example, an examination of box plots revealed that the data contained no outliers. The data were transformed to achieve a normal distribution assumption on the dependent variable, as indicated by the Shapiro-Wilks test ($P = 0.294$). The homogeneity of variances assumption was also satisfied, as indicated by Levene's test of equivalence of error variances ($P = 0.947$). Having met these assumptions, an analysis of variance statistics was applied to the students' performance for the HOT test scores of both groups.

Consequently, to analyze student performance in tackling HOT tasks, the mean scores and standard deviations for students' responses to the HOT test have been measured and compared for both study groups. Table 4 shows the obtained mean scores and standard deviations of the students' HOT task performance.

Table 4. Sample size, mean score, and standard deviation of the HOT tasks performance

Instructional method	Sample size	Mean score	Standard deviation
Traditional	30	23.10	8.486
ChatGPT-based	23	28.74	9.896
Total	53	25.55	9.463

Figure 3 indicates that the mean scores of student responses on HOT tasks in the AI technology-based experimental group (mean score = 28.74) exceeded that of the traditional control group (mean score = 23.10). We observed that the students who used ChatGPT during their OS learning outperformed the students who learned traditionally and responded better to HOT OS tasks.

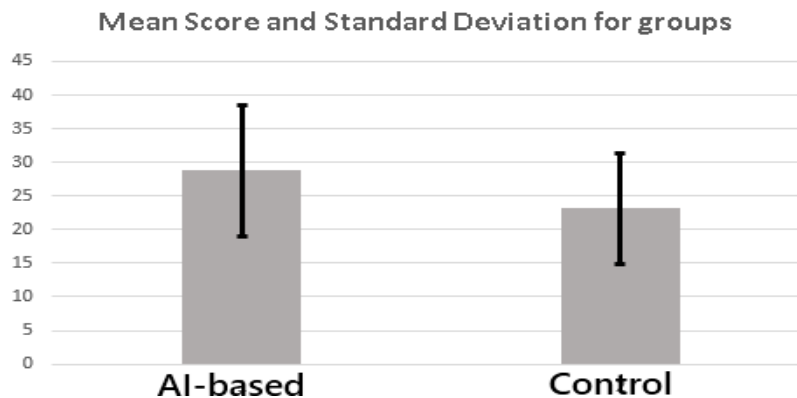


Figure 3. Mean scores for AI technology-based experimental group and control group

Accordingly, to determine whether the difference in the performance between the experimental and control groups is statistically significant and to determine how the teaching strategy affected the students' performance on HOT OS tasks, we conducted an analysis of variance, as shown in Table 5. To ascertain the results' practical importance, the effect size was also calculated.

Table 5. Analysis of variance results of students' test in HOT OS tasks

Source	Type III SS.	DF	MS.	F value	Sig.	Partial η^2
Instructional method	413.997	1	413.997	4.977	0.030	0.089
Error	4242.635	51	83.189			
Total	39247.500	53				

The analysis of variance results revealed a statistically significant effect of the AI technology-based instructional method on students' responses to HOT tasks in OS ($F [1,51] = 4.977$, $P = 0.030$), ($P < 0.05$) with a medium effect size (partial $\eta^2 = 0.089$). The obtained results suggest that 8.9% of the total variance in the students' performance on HOT tasks was attributable to the AI technology-based instructional method (Cohen, 2013). The AI technology-based instructional method using ChatGPT improves students' performance and enhances their responses to HOT OS tasks. This finding suggests that students' performance and their responses to HOT OS tasks might be improved according to the instructional method adopted for the experimental study group.

DISCUSSION

In this study, we propose an AI technology-based learning model using ChatGPT and investigate its effect on the performance of undergraduate students at Al al-Bayt University in Jordan when undertaking HOT OS tasks. The results showed a positive effect of the AI technology-based instructional method using ChatGPT on the students' performance in handling HOT tasks, which outperformed traditional methods. This result suggests that students who studied using AI-based instruction were enabled to analyze, evaluate, and create new knowledge when exposed to in-class ChatGPT activities that enriched their HOT responses and skills. This exposure to HOT OS problems and obtaining their solutions using ChatGPT improved students' ability to handle such advanced tasks. The findings are consistent with the theory of constructivism in that learners acquire, retain, and construct knowledge individually and interactively under their preferences and control using ChatGPT activities involved in the proposed learning model. Indeed, constructivism theory emphasizes the active role of learners in building their own understanding, which is achieved in the proposed learning model. The result is consistent with previous studies (Kortemeyer, 2023; Oktradiksa et al., 2021; Popenici & Kerr, 2017; Rowe & Lester, 2020; Zhu et al., 2023), which reported positive effects from using AI chatbots such as ChatGPT in several educational contexts and in several dimensions, and specifically in IT education (Biswas, 2023; Chen et al., 2023; Qureshi, 2023; Yilmaz & Karaoglan Yilmaz, 2023). The performance of students' HOT reported in this study is in line with the survey study of Guo and Lee (2023) about the usefulness of ChatGPT in developing HOT skills, which revealed a significant improvement in students' self-perception of their critical thinking competence and comprehension of complex subjects.

In contrast, the obtained result in this study contradicts several other findings that revealed unsatisfactory performance of using ChatGPT in other contexts and domains such as mathematics (Frieder et al., 2023) and (Wardat et al., 2023), sports science and psychology (Methnani et al., 2023; Szabo, 2023), and software testing and training (Ahmad et al., 2023) and (Zhang et al., 2023). Potential reasons might relate to subject domain issues and requirements or correspond to the deployment method of ChatGPT within other instructional activities. Instead of providing open and unguided use of ChatGPT, we limit ChatGPT use for each lecture to a predetermined HOT problem related to a specific HOT objective. The present study confirms that enabling students to interact with ChatGPT individually but within predetermined and specific problems, guided by HOT objectives

and under the instructor's guidance, helps students obtain the required support and reduce potential consequences (Guo & Lee, 2023). Another reason might be related to the misuse of ChatGPT by students by obtaining feedback knowledge and submitting the answers without refining or revising the result. This confirms the importance of students' self-summarization and the final discussion required by the proposed learning model.

Students' ability to handle complex and advanced OS topics and respond to and tackle HOT OS tasks is improved by appropriately using ChatGPT activities in the classroom. Interacting with ChatGPT with prompts about predetermined HOT problems related to HOT objectives increased students' curiosity and improved their motivation. The proposed learning model changes the role of students from knowledge receivers to self-learners who construct their own knowledge. The process of analyzing solution alternatives, finding the best one, and constructing an overall solution made by each student increases their self-confidence and improves their HOT. The proposed AI technology-based instructional model using ChatGPT enables the students to practice interactive learning and construct the required knowledge according to their preferences and capabilities in such a way that satisfies individual differences. ChatGPT has access to a huge amount of information regarding various OS problems, alternative solutions, and illustrations that can satisfy students' needs and improve their creativity and critical thinking. Accordingly, ChatGPT's responses simplify complex HOT problems by providing solutions in several steps, and each step is presented by various methods. Students can create the final best solution.

Blending ChatGPT activities within traditional OS instructional activities satisfies students' diverse and varied learning needs, styles, and preferences, resulting in more effective engagement and a better understanding of its complex topics. Such an AI-based mix allows students to perform real-time inquiries about diverse OS problems, obtain specific and instant feedback, and obtain flexible responses that adapt to their evolving dynamic needs. This ultimately helps in tailoring the OS instruction to students' individual needs and is more effective in developing their HOT.

In sum, adding ChatGPT activities to classroom instruction as a complementary tool under the guidance of instructors has contributed to improving the performance of students and their responses to HOT tasks in several dimensions. First, the conversational nature of ChatGPT can help reduce the boredom and frustration that students may experience when playing knowledge receiver roles. OS students may feel more comfortable asking ChatGPT questions rather than their teachers or peers, which reduces anxiety and self-consciousness, allowing students to seek help without fear of judgment. Second, ChatGPT can serve as a valuable supplemental learning tool alongside traditional educational resources by providing additional practical activities, explanations, and reinforcement of advanced concepts covered in class. Furthermore, ChatGPT may be adaptable to each student's requirements and preferences during their interactive sessions. ChatGPT may provide personalized explanations and resources based on each student's preferred level of knowledge by evaluating their questions and interactions.

IMPLICATIONS

Before incorporating ChatGPT into lesson plans, it's important to identify clear learning objectives, especially HOT ones, determine what students should learn in each session, and how ChatGPT can assist in achieving those goals. ChatGPT also should be used as a complementary tool that enhances learning instead of replacing traditional teaching methods. For instance, instead of simply relying on ChatGPT for study, students are required to use ChatGPT as a part of the lecture to gather information and construct new knowledge for precise and predetermined problems. Additionally, it's important to provide adequate guidance and ongoing support for ChatGPT use to ensure efficient use. Supported by constructivism theory, the proposed learning model integrated ChatGPT into teaching practices by granting students an active role in building their own understanding during in-class in-

struction rather than passively receiving information from the instructor. Additionally, by the interaction of prior knowledge they have, students were enabled to analyze, evaluate, and create new knowledge to incorporate into their schemas and experiences.

This study provides several important implications for both research and practice. First, this is one of the few studies that investigate and measure ChatGPT's ability to foster students' HOT. Various previous research in the literature primarily focused on the effect of ChatGPT on students' performances in several dimensions, such as achievement, motivation, and engagement; this research enriches the literature and offers insights for future studies. Second, this study extends the application of the constructivism theory in the literature to the integration of AI-based activities within other instructional activities. The empirical evidence regarding the effect of ChatGPT on the HOT of students confirms the findings from previous studies in the literature that the appropriate instructional design and use of AI chatbots are important to foster students' HOT and improve their performance.

From a practitioner's perspective, this study encourages educational institutes to take into consideration the recent developments in AI-based technologies and the tremendous number of their applications and include AI-based activities in their course plans and instruction. It is useful for educational institutes to have dedicated AI-based activities in their course outlines and instructional processes. Indeed, AI-based activities are helpful for teachers by reducing instructional workloads of higher quality and are useful for students by offering personalized and interactive learning experiences to construct new knowledge. Clearly, as the number of AI-based applications grows, practitioners could benefit from the findings of this study by better identifying a helpful design that best integrates AI-based instructional activities in a way that reduces the consequences and increases the benefits.

CONCLUSION

This study introduces an enhanced AI technology-based learning model using ChatGPT based on the principles of the theory of constructivism to help students address and solve HOT OS tasks and issues. By highlighting the significance of using ChatGPT in the classroom and demonstrating best practices for integrating and optimizing the design of ChatGPT activities, this study provides innovative additions to the related literature. Empirical findings demonstrate that students' performance in and responses to HOT OS tasks were improved by the suggested AI technology-based learning model utilizing ChatGPT activities. The results show that students were more likely to complete HOT tasks effectively when they studied using the proposed AI technology-based learning model and were exposed to ChatGPT in-class activities.

Incorporating ChatGPT as a complementary tool with other teaching strategies stimulates students' critical thinking and creativity by increasing their engagement and motivation. Such features made this approach an adequate educational mixture between the human elements on the one hand and artificial intelligence on the other. Indeed, each lecture is intended to solve a specific HOT problem addressed by the instructor and find a personalized solution using ChatGPT. Each student can construct knowledge based on previous information he has owned individually. ChatGPT responses provide several alternative solutions that help students analyze, evaluate, and create a new self-understanding of OS topics, which fosters critical thinking.

Incorporating ChatGPT also helped generate OS problems that provoke students' HOT, create solutions, and discuss alternative methods to reach a clear explanation. ChatGPT can receive any additional detailed information related to HOT topics to improve student responses and better explain and solve HOT tasks. ChatGPT has played the role of assistant teacher, which is the primary way it contributes to improving students' performance. Furthermore, ChatGPT helps review basic concepts and generalizations and creatively reorganizes ideas about OS.

Although real-time feedback can assist students in performing self-summarization and self-evaluation, ChatGPT permits self-learning according to students' differences and creates better understanding using a repeatable method. Students can revise and express the knowledge they have learned through AI conversation by completing self-summarization exercises. Students can share new thoughts and experiences that have occurred during interactive learning by self-evaluating. This study offers valuable information about using AI chatbots for suitable activities in instructional design. It expands current research on AI-based learning and has important ramifications for both practice and research. Higher education must integrate ChatGPT into traditional teaching methods to motivate students to regularly access and apply the most recent knowledge and HOTS problems to enhance their performance. It also helps educational institutions become more sustainable by attracting elite students and improving student satisfaction and achievement levels.

Overall, students in the OS class can enhance their learning, receive personalized support, and eventually enhance their ability to complete HOTS tasks by utilizing ChatGPT features. It is imperative to mention that although ChatGPT can be a useful instrument, it needs to be employed with other educational tools; it should not replace human guidance and assistance.

However, students with less patience, less motivation, and fewer communication skills with ChatGPT to obtain the right answers that can satisfy the required questions have practical limitations that influenced the obtained results and reduced the effect size of this study. Additional training on ChatGPT communication and using motivating factors for students might be useful and provide additional insights to overcome such limitations. Further research is needed to explore whether AI-based instruction can be used effectively in other courses with diverse contextual variables and suitable in-class activity designs. To obtain better outcomes, we advise focusing more on educational approaches in conjunction with AI chatbots and substitutes. It is advisable to investigate the impact of utilizing AI chatbots on additional characteristics, including motivation, engagement, self-efficacy, and academic self-perception. Additional problems to consider are managing students' conduct during in-class activities and utilizing the right AI chatbot for the subject. Finally, the study's limitations should be acknowledged, including subject area, sample size, and other environmental variables. We advise repeating this study with a larger number of students in different contexts and in other academic courses offered by different colleges and universities.

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APPENDIX A: AN AI-BASED INTERACTIVE SESSION INITIATED BY THE INSTRUCTOR AS AN EXAMPLE

Main objective: Understanding CPU Scheduling Algorithms.

Lecture sub-objective: Understand Shortest Job First (SJF) CPU Scheduling Algorithm.

The first part:

- The instructor introduces the concept of the Shortest Job First (SJF) CPU scheduling algorithm and how processes are scheduled based on arrival and burst time to optimize system performance.

The second part (ChatGPT-based activity details):

- Problem details (Analysis and Evaluation):
 - ✓ Students are required to analyze the characteristics and behavior of the SJF scheduling algorithm and evaluate how SJF minimizes waiting times, maximizes throughput, and optimizes system performance compared to other algorithms.
- Potential questions for ChatGPT:
 - ✓ We have two processes (A and B) arriving at different times with varying burst times (A arriving at 0 with burst time 4, B arriving at 0 with burst time 3). How can I schedule these processes using the SJF algorithm and calculate the average waiting time and average turnaround time?
 - ✓ Give me a CPU scheduling problem as an example, with 2 processes only.
 - ✓ Give me a CPU scheduling problem as an example, with 2 processes and different arrival and burst times.
 - ✓ Give me an unstraightforward example of the SJF algorithm, with ...
 - ✓ Summarize the latest given solution.
 - ✓ Summarize the solution for the specified step, i.e., calculated waiting of process p2.
 - ✓ Explain why p is executed after p2 completes.
 - ✓ What changes are required for the last example to let p2 execute before p1 and after p3?
 - ✓ Can I have the answer with more visual data?

APPENDIX B: AN EXAMPLE OF A CHATGPT INTERACTION SESSION RELATED TO THE SJF PROBLEM

One of the students communicating with the ChatGPT shows questions posted and responses generated while performing the following tasks:

1. Request a step-by-step solution for a given problem to build a new understanding.
2. Request additional straightforward SJF examples to enhance the new understanding.
3. Request additional advanced (unstraightforward) examples to support and improve HOT.
4. Request advanced explanation to perform self-evaluation.
5. Request further explanation that supports HOT.
6. Request further precise explanations that improve HOT.
7. Request advanced HOT examples with specific requirements to enhance critical thinking.
8. Further request to enhance the HOT understanding.

Task 1: Request a step-by-step solution for a given problem to build a new understanding. We have two processes (A and B) arriving at different times with varying burst times (A arriving at 0 with burst time 4, B arriving at 0 with burst time 3). How can I schedule these processes using the SJF algorithm and calculate the average waiting time and average turnaround time?

We have two processes (A and B) arriving at different times with varying burst times (A arriving at 0 with burst time 4 ,B arriving at 0 with burst time 3). How I can schedule these processes using the SJF algorithm and calculate the average waiting time and average turnaround time.



Let's solve this CPU scheduling problem using the Shortest Job First (SJF) algorithm. Since both processes arrive at the same time (time 0), the process with the shorter burst time will be scheduled first.

Problem Statement

We have two processes with the following arrival times and burst times:

Process	Arrival Time	Burst Time
A	0	4
B	0	3

Steps to Solve Using SJF Algorithm

1. Initialization:



- Current time = 0

Task 2: Request a new straightforward example of the SJF algorithm to enhance the new understanding.

give me cpu scheduling problem as an example



Sure! Here's a CPU scheduling problem example for you to solve using the Shortest Job Next (SJN) / Shortest Job First (SJF) algorithm:

Problem Statement

You have four processes arriving at different times with varying burst times. Your task is to schedule these processes using the SJN/SJF algorithm and calculate the average waiting time and average turnaround time.

Processes

Process	Arrival Time	Burst Time
P1	0	8
P2	1	4
P3	2	9
P4	3	5

Steps to Solve



1. List all processes along with their arrival times and burst times.

Task 3: Request advanced examples to support and improve HOT.

Give me an unstraightforward example of the SJF algorithm, with 3 process only



Certainly! Let's consider an example with three processes arriving at different times with varying burst times. This will demonstrate how the Shortest Job First (SJF) algorithm handles processes that arrive at different times.

Problem Statement

We have three processes with the following arrival times and burst times:

Process	Arrival Time	Burst Time
P1	0	8
P2	1	4
P3	2	9

Steps to Solve Using SJF Algorithm

1. Initialization:

- Current time = 0
- Waiting time and turnaround time for all processes = 0

Task 4: Request advanced explanation to perform self-evaluation.

summarize the solution



Summary of the SJF Scheduling Example

Given Processes

Process	Arrival Time	Burst Time
P1	0	8
P2	1	4
P3	2	9

Scheduling Steps

1. At time 0:
 - Only P1 has arrived. Schedule P1.
2. From time 0 to 8:
 - P1 is executing.
3. At time 8:
 - P1 completes. P2 and P3 have arrived.
 - P2 has the shorter burst time (4), so schedule P2.

Task 5: Request further explanation that supports HOT.

summarize the solution for Calculated Waiting and Turnaround Time of P3



Calculated Waiting and Turnaround Time for P3

Details

- Arrival Time: 2
- Burst Time: 9

Scheduling Steps Involving P3

1. P3 arrives at time 2 but starts execution only after P2 completes.
2. P2 completes at time 12, so P3 starts at time 12.

Calculation

- **Waiting Time for P3:**
 - Waiting Time = Start Time of P3 - Arrival Time of P3
 - Waiting Time = 12 - 2 = 10
- Turnaround Time for P3:



Task 6: Request further precise explanation that improves HOT.

explain why p3 starts execution after P2 completes



In the Shortest Job First (SJF) scheduling algorithm, the process with the shortest burst time among the available (arrived) processes is selected for execution next. Here's a detailed explanation of why P3 starts execution after P2 completes in this example:

Given Processes

Process	Arrival Time	Burst Time
P1	0	8
P2	1	4
P3	2	9

Scheduling Steps and Explanation

1. At time 0:
 - Processes Available: P1
 - Selected Process: P1 (since it is the only process available)
 - Execution: P1 starts and runs from time 0 to 8.
2. At time 8:



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